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TITLE OF THE INVENTION

METHOD AND APPARATUS FOR IMAGE FORMING WITH DUAL OPTICAL SCANNING SYSTEMS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This patent specification relates to a method and apparatus for image forming, and more particularly to a method and apparatus for image forming that uses dual optical scanning systems.

DISCUSSION OF THE BACKGROUND

An image forming apparatus, including a copying machine, a laser printer, etc., increasingly use digital processing. This tendency also has occurred with a wide format image forming apparatus capable of handling an A1 sheet, an A0 sheet, etc. Consequently, demand for a high image quality in the wide format image forming apparatus is increasing. Currently, an optical writing apparatus using a light-emitting diode (LED) is used in digital copying machines capable of handling a wide format such as A1, A0, etc. In comparison to an optical writing apparatus using a laser beam scanning method, an optical writing apparatus using an LED is generally high in cost and is rather inferior in quality.

However, with laser scanning over an A0 width, various factors such as light lengths, sizes of lenses, reflection

mirrors having long lengths, etc. result in problems such as an upsizing of units and an increasing cost. In attempting to solve these problems, various techniques have been developed in which two optical scanning systems are adjoined in a main scanning direction to obtain a wide scanning capability.

For example, optical writing apparatuses for a wide format using two optical scanning systems and including two polygon mirrors are described in Japanese unexamined patent publications, No. 61-11720, No. 62-169575, and No. 6-208066. No. 61-11720 and 62-16952 use a method of adjoining two scanning lines that scan in the same direction and require a synchronization between the rotations of the two polygon mirrors to justify positions of the scanning lines in the sub-scanning direction. No. 6-208066 controls two scanning lines which begin from the center of the scanning width and move towards different ends in the main scanning direction by rotating the two polygon mirrors in different directions from each other. One mirror rotates in a forward direction and the other mirror rotates in a reversed direction.

Another method is described in Japanese unexamined patent publication, No. 8-72308, in which two polygon mirrors are rotated with a single driving source. An optical scanning method is used in which two beams are directed to different surfaces of a single polygon mirror. The two scanning beams are adjoined in the main scanning direction with a common optical focusing system.

Further, Japanese unexamined patent publications, No.9-5655 and No. 9-127440, describe other optical scanning apparatuses which use two or more polygon mirrors and two or more optical focusing systems.

Further, Japanese unexamined patent publication, No. 2000-187171, describes an optical scanning apparatus in which two light beams are deflected with a common polygon mirror.

However, the above-mentioned optical scanning apparatus cause a problem in which two scanning lines are not precisely matched in a sub-scanning direction at the starting positions.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, a novel optical scanning apparatus includes at least two light sources, at least two beam shaping mechanisms, a light deflector, and at least two scanning beam focusing mechanisms. Each of the two light sources is arranged and configured to emit a light beam. Each of the two beam shaping mechanisms is arranged and configured to shape the light beam. The light deflector is arranged and configured to deflect each light beam in a continuously changing direction thereby converting each light beam into a scanning light beam. Each of the two scanning beam focusing mechanisms is arranged and configured to bring the scanning light beam to a focus on a photoconductive surface. Each of the two scanning beam focusing mechanisms each of which produce a beam which

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satisfies an equation of $\Delta L\cos\alpha > R/2$ at a junction of the first scanning light beam with the second scanning light beam on the photoconductive surface, wherein ΔL represents an inherent light pass length variation, α represents an incident angle, and R represents an inherent marginal distance.

According to another aspect of this invention, a method of optical scanning includes the steps of emitting at least two light beams, shaping the at least two light beams, deflecting each of the at least two light beams in a continuously changing direction thereby converting each of the at least two light beams into a scanning light beam, and bringing the scanning light beam to a focus on a photoconductive surface with at least two scanning beam focusing mechanisms each of which produce a beam. Each beam satisfies an equation of $\Delta L\cos\alpha > R/2$ at a junction of the at least two scanning light beams with each other on the photoconductive surface, wherein ΔL represents an inherent light pass length variation, α represents an incident angle, and R represents an inherent marginal distance.

According to another aspect of the invention, an image forming apparatus includes a photoconductive member and an optical scanning apparatus. The optical scanning apparatus includes at least two light sources, at least two beam shaping mechanisms, a light deflector, and at least two scanning beam focusing mechanisms. Each of the two light sources is arranged and configured to emit a light beam. Each of the two

beam shaping mechanisms is arranged and configured to shape the light beam. The light deflector is arranged and configured to deflect each light beam in a continuously changing direction thereby converting each light beam into a scanning light beam. Each of the two scanning beam focusing mechanisms is arranged and configured to bring the scanning light beam to a focus on a surface of the photoconductive member and satisfies an equation of $\Delta L\cos\alpha > R/2$ at a junction of the at least two scanning light beams with each other on the surface of the photoconductive member, wherein ΔL represents an inherent light pass length variation, α represents an incident angle, and R represents an inherent marginal distance.

According to another aspect of the present invention, a method of image forming includes the steps of charging a surface of a photoconductive member, emitting at least two light beams, shaping the at least two light beams, deflecting each of the at least two light beams in a continuously changing direction so as to convert each of the at least two light beams into a scanning light beam, and bringing the at least two scanning light beams to a focus on the surface of the photoconductive member with at least two scanning beam focusing mechanisms. Each of the at least two scanning beam focusing mechanism which produce a beam which satisfies an equation of $\Delta L\cos\alpha > R/2$ at a junction of the at least two scanning light beams with each other on the photoconductive

surface, wherein ΔL represents an inherent light pass length variation, α represents an incident angle, and R represents an inherent marginal distance.

According to another aspect of the present invention, each of the two scanning beam focusing mechanisms may include a telecentric $f\theta$ lens system or a telecentric $f\theta$ mirror system.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Fig. 1 is a schematic diagram of an optical scanning apparatus according to a preferred embodiment;

Fig. 2 is a schematic diagram of an optical lens systems using a telecentric $f\theta$ lens;

Fig. 3 is a schematic diagram of an optical lens system using a wide-angle lens;

Fig. 4 is a schematic diagram of an optical scanning apparatus according to an alternate embodiment; and

Fig. 5 is a schematic diagram of an image forming apparatus that may use the optical scanning system of Fig. 1 or Fig. 4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In describing preferred embodiments illustrated in the drawings, specific terminology is used for the sake of clarity. However, the disclosure of this patent specification is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner. Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, a description is provided for an optical scanning apparatus of the present invention and an image forming apparatus arranged with the above-mentioned optical scanning apparatus.

Fig. 1 illustrates an optical scanning apparatus 100 according to a preferred embodiment of the present invention. The optical scanning apparatus 100 includes two optical scanning systems S1 and S2. As illustrated in Fig. 1, the optical scanning system S1 includes a light source 1-1, a collimate lens 2-1, a cylindrical lens 3-1, a first $f\theta$ lens 5-1, a second $f\theta$ lens 6-1, a first mirror 7-1, and a second mirror 8-1, a third mirror 9-1, and a synchronous beam detector 10-1. Likewise, the optical scanning system S2 includes a light source 1-2, a collimate lens 2-2, a cylindrical lens 3-2, a first $f\theta$ lens 5-2, a second $f\theta$ lens 6-2, a first mirror 7-2, and a second mirror 8-2, a third mirror 9-2, and a synchronous beam detector 10-2. In

describing the optical scanning systems S1 and S2, the reference numeral before a hyphen indicates a component and the reference numeral 1 or 2 after hyphen indicates whether the component belongs to the optical scanning system S1 or S2, respectively. For example, the light sources 1-1 and 1-2 are identical as components but the light source 1-1 belongs to the system S1, and the light source 1-2 belongs to the optical scanning system S2. The optical scanning apparatus 100 further includes a polygon mirror 4 which is used by both the optical scanning systems S1 and S2. In Fig. 1, reference numeral 11 denotes a photoconductive member.

The light sources 1-1 and 1-2 emit light beams. The light sources 1-1 and 1-2 may be a laser diode for emitting a laser beam, a laser diode array for emitting a plurality of laser beams, a device of a laser diode combined with an optical device for emitting a plurality of laser beams, or any other appropriate light source. The collimate lenses 2-1 and 2-2 collimate a light beam and are arranged at positions to pass the light beams emitted by the light sources 1-1 and 1-2, respectively. The cylindrical lenses 3-1 and 3-2 gather diverging rays in one direction into an intensive light beam and are arranged at positions so that the light beams passing through the collimate lenses 2-1 and 2-2, respectively, impinge on the polygon mirror 4. The polygon mirror 4 is a light deflecting mechanism and includes a plurality of deflecting surfaces for deflecting light beams. The polygon

mirror 4 is rotated by a driving mechanism such as a motor (not shown) at a predetermined speed so that the deflecting surfaces continuously change angles relative to the incident light beams. Thus, the light beams become scanning light beams.

The first fθ lenses 5-1 and 5-2 have a predetermined width to receive the scanning light beams deflected by the polygon mirror 4, and the second fθ lenses 6-1 and 6-2 have a predetermined width to receive the scanning light beams passing through the first fθ lenses 5-1 and 5-2. The first fθ lens 5-1 and the second fθ lens 6-1 form a scanning beam focusing mechanism for the optical scanning system S1. The first fθ lens 5-2 and the second fθ lens 6-2 form a scanning beam focusing mechanism for the optical scanning system S2.

In the optical scanning system S1, the first, second, and third mirrors 7-1, 8-1, and 9-1 are arranged at positions to reflect in turn the scanning light beam transmitted from the second fθ lens 6-1 to a surface of the photoconductive member 11. In the optical scanning system S2, the first, second, and third mirrors 7-2, 8-2 and 9-2 are arranged at positions to reflect in turn the scanning light beam transmitted from the second fθ lens 6-2 to a surface of the photoconductive member 11.

In the optical scanning system S1, the light source 1-1 is driven by a driving control mechanism (not shown) to emit a light beam that is modulated in accordance with an image

signal. The light beam is collimated and sharpened with the collimate lens 2-1 and the cylindrical lens 3-1, and is converted by the rotating surfaces of the polygon mirror 4 into a scanning light beam. The scanning light beam, which is a light beam running at a constant angular speed, is converted into a scanning light beam that runs at a constant speed with the first and second f θ lenses 5-1 and 6-1. The travel direction of the scanning light beam running at the constant speed is changed with the first and second mirrors 7-1 and 8-1, and is finally directed to the surface of the photoconductive member 11 with the third mirror 9-1. Consequently, the scanning light beam starts scanning from a predetermined central position towards one end portion of the surface of the photoconductive member 11.

The optical scanning system S2 includes a structure similar to that of the optical scanning system S1 and is situated at a position rotated about the polygon mirror 4 by 180 degrees from a position of the optical scanning system S1. In this optical scanning system S2, the light source 1-2 is driven by a light source driving controller (not shown) to emit a light beam that is modulated in accordance with an image signal. The light beam is collimated and sharpened with the collimate lens 2-2 and the cylindrical lens 3-2, and is converted, with the rotating surfaces of the polygon mirror 4, into a scanning light beam. The scanning light beam, which is a light beam running at a constant angular speed, is converted

into a scanning light beam that runs at a constant speed with the first and second f θ lenses 5-2 and 6-2. The travel direction of the scanning light beam running at constant speed is changed with the first and second mirrors 7-2 and 8-2, and is finally directed to the surface of the photoconductive member 11 with the third mirror 9-2. Consequently, the scanning light beam starts scanning from a predetermined central position towards the other end portion of the surface of the photoconductive member 11.

The synchronous beam detectors 10-1 and 10-2 are arranged outside areas of passage for the light beams covered by the respective deflecting mechanisms so as to detect the beginning of each light beam. Based on this detection, an image writing controller (not shown) determines a scanning start position each time of scanning begins and controls a time to start image writing on the surface of the photoconductive member 11.

The optical scanning apparatus 100 of Fig. 1 controls the optical scanning systems S1 and S2 in a manner such that the light beams modulated in accordance with image information scan from the predetermined central positions towards the respective ends of the surface of the photoconductive member 11.

In this example, the optical scanning systems S1 and S2 employs a telecentric optical system to attain an incident angles A1 and A2 of approximately 90 degrees which are

respectively formed between the light beams and the surface of the photoconductive member 4 in the scanning direction in an effective writing area.

Fig. 2 illustrates one example of a telecentric fθ lens system L1 that may be used by the scanning beam focusing mechanism of the optical scanning apparatus 100 of Fig 1. In the telecentric fθ lens system of Fig. 2, light rays of a light beam are directed to a photoconductive surface P in a direction normal to the photoconductive surface P. Therefore, an image focused on the photoconductive surface P remains the same when a passage length of the light rays is changed, for example, by a movement of the photoconductive surface P by a distance V1, as illustrated in Fig. 2.

Referring to Fig. 3, a wide-angle fθ lens system L2 focuses an image on the photoconductive surface P with a light ray having an incident angle θ which is continuously reduced from 90 degrees as the light ray goes outside the center in the main scanning direction. Therefore, an image focused on the photoconductive surface P is changed when a passage length of the light ray is changed, for example, by a movement of the photoconductive surface P by a distance V2, as illustrated in Fig. 3. This causes a change of a space between pixels in the sub-scanning direction. The change is continuously increased as the light ray goes outside the center in the main scanning direction or as the photoconductive surface P is moved away from the wide-angle lens system L2.

Therefore, a scanning beam focusing mechanism using the telecentric fθ lens system, as illustrated in Fig. 2, is affected less by movement of a photoconductive surface than the one using the wide-angle fθ lens system.

In addition, the optical scanning systems S1 and S2 may cause variations of the scanning position at a junction where scanning by the light beams of the optical scanning systems S1 and S2 are adjoined. Incident angles of the light beams passing through the optical scanning systems S1 and S2 have opposite phases to each other. Consequently, the variations of the scanning position cause additional variations of the scanning positions produced by the optical scanning systems S1 and S2. Therefore, the amount of variations of the scanning position at the junction is desirably within half of a marginal distance R which is a minimum distance allowable between two adjacent pixels and is inherent to each optical scanning system.

An optical scanning system includes the inherent marginal distance R and a light pass length variation ΔL which is also inherent to the optical scanning system. Accordingly, an optical scanning apparatus using the optical scanning system has an inherent marginal distance R and an inherent light pass length variation ΔL. To satisfy a required performance, an optical scanning apparatus include a mechanism for reducing the variations of the light pass length or correcting the displacement at the junction in accordance with

the variations of the light pass length, or satisfying an equation $\Delta L \cos \alpha > R/2$, wherein the light pass length variation ΔL, the incident angle α at the junction, and the marginal distance R.

Referring to Fig. 4, an alternate optical scanning apparatus 200 is described. The optical scanning apparatus 200 uses a telecentric fθ lens system and includes the light source 1, the collimate lens 2, the cylindrical lens 3, and the polygon mirror 4, which are identical to those components described above in reference to the optical scanning apparatus 100. The optical scanning apparatus 200 further includes an eccentric toric lens 16, a telecentric fθ mirror 17, a mirror 18, a synchronous beam detector 19, a light gathering lens 20, and a silicon on sapphire type (SOS-type) sensor 21.

In the optical scanning apparatus 200, the telecentric fθ mirror 17 directs rays of a scanning light beam to the surface of the photoconductive member 11 and in a direction normal to the surface of the photoconductive member 11. Therefore, effects on the optical scanning apparatus 200 from movement of an object surface is minimized, as compared to the scanning beam focusing mechanism using the telecentric fθ lens system. Thus, an optical lens system using the telecentric fθ mirror 17 can be used in the optical scanning apparatus 100 as an alternative to the telecentric fθ lens system.

In general, a telecentric fθ lens is composed of a glass lens and has advantages of a small thermal sensitivity and a

consequent high-precision capability. The telecentric f θ mirror advantageously has a space-saving capability if combined with an aspheric lens.

While the discussion for the two optical scanning systems implemented in the optical scanning apparatus is discussed with reference to Fig. 1, it should be clear that the disclosure applies to other structures that has been developed for adjoining two scanning light beams.

Referring to Fig. 5, an exemplary structure of an image forming apparatus 300 includes the optical scanning apparatus 100. The image forming apparatus 300 also includes the photoconductive member 11, a charge member 22, a development unit 24, a recording sheet cassette 25, a sheet feed roller 26, a registration roller 27, a transfer roller 28, a fixing unit 29, a cleaning unit 30, and a discharger 31.

The charge member 22 evenly charges the surface of the photoconductive member 11 on which an electrostatic latent image is drawn by the scanning light beams generated by the optical scanning apparatus 100. The development unit 24 develops the electrostatic latent image formed on the photoconductive member 11 with toner into a visual toner image. The recording sheet cassette 25 contains a plurality of recording sheets. The sheet feed roller 26 picks up and transfers a recording sheet from the recording sheet cassette 26. The registration roller 27 stops and transfers the recording sheet transferred by the sheet feed roller 26 in

synchronism with a rotation of the photoconductive member 11 carrying the toner image. The transfer unit 28 transfers the toner image carried on the photoconductive member 11 onto the recording sheet, and then transfers the recording sheet carrying the toner image. The fixing unit 29 fixes the toner image with heat and/or pressure onto the recording sheet. The cleaning unit 30 removes the residual toner from the surface of the photoconductive member 11, after the transfer unit 28 transfers the toner image to the recording sheet. The discharger 31 discharges residual charges on the surface of the photoconductive member 11, after the cleaning unit 30 removes the residual toner from the surface of the photoconductive member 11.

In image forming apparatus 300, the scanning light beams emitted by the optical scanning apparatus 100 on the evenly charged surface of the photoconductive member 11 form an electrostatic latent image. In synchronism with a rotation of the photoconductive member 11, a recording sheet is transferred to the transfer roller 28 by the registration roller 27 after being picked up and fed from the recording sheet cassette 25 by the sheet feed roller 26. Then, the toner image is transferred from the photoconductive member 11 to the recording sheet which is then forwarded to the fixing unit 29. The toner image is fixed onto the recording sheet with heat and/or pressure and is ejected outside the image forming apparatus 300.

Accordingly, the image forming apparatus 300 may produce an image of relatively high quality with the optical scanning apparatus 100 that eliminates the above-mentioned problem of displacement at the junction point caused by variations of the light passage length and that is produced in a relatively low cost and a compact design.

As an alternative to the optical scanning apparatus 100, the image forming apparatus 300 may include the optical scanning apparatus 200.

Numerous additional modifications and variations are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the disclosure of this patent specification may be practiced otherwise than as specifically described herein.

This patent specification is based on Japanese patent application, No. JPAP2001-076163 filed on March 16, 2001, in the Japanese Patent Office, the entire contents of which are incorporated by reference herein.